

7. PRODUCTS AND SERVICES

7.1. METOC PRODUCTS

NAVPACMETOCCEN WEST/JTWC issues area and specialized forecasts for units in its AOR. Area forecasts include high wind/seas forecasts, tropical warnings and prognostic blend charts valid to 120 hours. Specialized forecasts include WEAX, OTSR services and acoustic forecasts as requested.

7.1.1. PROGNOSTIC BLEND CHARTS

Prognostic blend charts are prepared by NPMOCW forecasters. These charts form the basis of all warnings and forecasts (except tropical cyclone warnings issued by JTWC).

7.1.1.1. WESTERN PACIFIC (WESTPAC) WEATHER DEPICTION SERIES

This series of locally produced surface prognoses depicts surface winds, pressure centers, ice edge, frontal boundaries, high wind and seas warning areas valid for the time period and tropical cyclone warnings. These charts are based upon satellite analyses, synoptic observations, numerical models (NOGAPS, NORAPS, NCEP, ECMWF and JMA) and input from JTWC. The series includes:

1. WESTPAC 36 HR WX Depiction
2. WESTPAC 84 HR WX Depiction
3. WESTPAC 120 HR WX Depiction

Tropical cyclone positions and intensities for the 36 products are derived from warnings issued by JTWC. Tropical cyclone positions and intensities for the 84- and 120-hr products are based on interpolation of current model runs and coordination with the Typhoon Duty Officer.

7.1.1.2. WESTPAC 36-HOUR SIGNIFICANT WAVE HEIGHT PROG

This chart depicts the significant wave height and direction based on the numerical WAM model and the 36 HR WX Depiction. Sea heights are indicated by 3, 6, 9, 12, 18 and 24 foot contours. The height and position of the maximum seas are indicated inside the highest contour.

7.1.1.3. INDIAN OCEAN 36-HOUR WEATHER DEPICTION

This locally produced surface prognoses depicts surface winds, pressure centers, frontal boundaries, areas of cloud cover 5/8 or more, high wind and seas warning areas valid for the time period and tropical cyclone warnings. This chart is based upon satellite analyses, synoptic observations, numerical models (NOGAPS, NCEP and ECMWF) and input from JTWC. Tropical cyclone positions and intensities are derived from warnings issued by JTWC.

7.1.1.4. INDIAN OCEAN 36-HOUR SIGNIFICANT WAVE HEIGHT PROG

This chart depicts the significant wave height and direction for the Bay of Bengal, North Arabian Sea, Arabian Gulf and Red Sea based on the numerical WAM model. Sea heights are indicated by 3, 6, 9, 12, 18 and 24 foot contours. The height and position of the maximum seas are indicated inside the highest contour.

7.1.2. WEAX AND OTSR

1. The purpose of Enroute Weather Forecasts (WEAX) is to provide requesting units operating within the AOR detailed, timely weather/METOC forecasts, in accordance with

NAVMETOCOMINST 3140.1 (series). WEAX forecasts are issued daily for units operating under normal conditions. Units operating under heavy weather conditions, towing or conducting special operations will be issued WEAX twice daily, at a minimum.

2. Optimum Track Ship Routing (OTSR) is an advisory service provided to requesting units transiting the AOR. OTSR provides recommended ship routes and revisions, if needed. Recommendations are designed to minimize time enroute and the risk of damage resulting from environmental phenomena. OTSR takes into consideration individual ship and cargo characteristics. For more detailed information, refer to NAVMETOCOMINST 3140.1 (series).

7.1.3. HIGH WIND AND SEAS WARNINGS

1. The High Wind and Seas warnings are issued twice daily for the WESTPAC and INDIAN OCEAN areas. The WESTPAC warning (WWPW 30/31) covers the area from 120° East to 180° and from 66° North to the Equator. The Bay of Bengal and Northern Arabian Sea (north of the Equator) are covered by the Indian Ocean Warning (WWIO 30/31). Arabian Gulf and the Red Sea wind and seas warnings (MASR 1 PGFW) are issued by NAVPACMETOC DET BAHRAIN.

2. The following are standard criteria used by all centers for their warnings:

a. Areas of wind speed of 35-49 knots (Gale); wind speeds of 50 knots or greater (Storm) not covered by a tropical warning.

b. Areas of sea heights greater than or equal to 12 feet. Warnings also contain maximum height and approximate positions of the maximum seas.

3. The High Wind and Seas Warnings are transmitted from NAVPACMETOCEN WEST GU via AUTODIN to AIG 127 for WESTPAC warnings and AIG 498 for Indian Ocean warnings. Warnings are also broadcast via the Fleet Broadcast, as an overlay on JMCIS and on the website.

7.1.4. HORIZONTAL REFRACTIVITY DEPICTION

This product describes areas of electromagnetic similarities. The HRD incorporates propagation loss, topography, local upper air soundings and synoptic patterns into the analysis.

7.1.5. WPAC FRONTS AND EDDIES

This product contains positions and intensities of fronts and eddies in the Western Pacific Ocean. Major fronts normally included are: Kuroshio, Oyashio, Tsushima, Liman-Tsushima, Korean Coastal and Yellow Sea. A number of unnamed fronts are also addressed. Resources for analysis include: sea surface temperature, enhanced infrared and visual satellite imagery, previous analyses and computer derived products. This product is transmitted twice weekly via AUTODIN and JOTSII.

7.1.6. INDIAN OCEAN FRONTS AND EDDIES

This product contains positions and intensities of fronts and eddies in the Arabian Gulf, Gulf of Oman, Red Sea, Northern Indian Ocean and the Bay of Bengal. This product is transmitted twice weekly via AUTODIN and JOTSII.

7.1.7. ENERGY SAVINGS USING OCEAN CURRENTS

This product identifies the geometry and intensity of the Kuroshio Current to aid ships in transiting between the South China Sea and Yokosuka, Japan. This product is derived from the FNMOC model products and transmitted twice weekly via AUTODIN only.

7.1.8. SURF FORECASTS

In response to requests from amphibious units, surf forecasts are prepared by the duty watch section. The section will prepare a surf forecast, providing detailed bathymetry near the operating area beaches and required graphic extracts from the Joint Surf Manual.

7.2. JTCW PRODUCTS

Two general types of products are provided by JTCW: routine and tropical cyclone related. The routine products include the Significant Tropical Weather Advisories for the Western Pacific and Indian Oceans. The tropical cyclone products are Tropical Cyclone Formation Alerts, Tropical Cyclone/Tropical Depression Warnings and Prognostic Reasoning Messages.

1. Significant Tropical Weather Advisory -- Issued at 0600Z for the Pacific and 1800Z for the Indian Ocean or more frequently as needed, to describe all tropical disturbances and their potential for further (tropical cyclone) development during the advisory period. For any suspect area mentioned, the words "poor", "fair" or "good" are used to describe the potential for development. "Poor" is used to describe a tropical disturbance in which further development is unlikely during the next 24 hours under the current meteorological conditions, and issuance of a Tropical Cyclone Formation Alert (TCFA) is not anticipated. "Fair" is used to describe a tropical disturbance in which conditions are improving and the issuance of a TCFA is likely within the next 24 hours. "Good" describes a tropical disturbance on which a TCFA is in effect. A separate scheduled bulletin is issued for the Western Pacific and Indian Ocean.

2. Tropical Cyclone Formation Alert (TCFA) -- Issued when synoptic and/or satellite data, or other germane data, indicate the development of a significant tropical cyclone is likely within the next 24 hours in a specified area. A TCFA will specify a valid period not to exceed 24 hours and must be either canceled, reissued or superseded by a warning prior to expiration.

3. Tropical Cyclone / Tropical Depression Warning -- Issued periodically throughout the day to provide forecasts of position, intensity and wind distribution for tropical cyclones within JTCW's AOR. There are two types of warnings: Tropical Cyclone warnings and Tropical Depression warnings.

(a) Tropical Cyclone Warning -- Issued when a closed circulation is evident and maximum sustained winds are forecast to reach 34 kt or greater within 48 hours, or when a tropical cyclone is in such a position that life or property may be endangered within 72 hours. In addition, warnings are issued for the Northwest Pacific when tropical systems reach 25 kt. Each Tropical Cyclone warning is numbered sequentially and includes: (1) the current position of the surface center, (2) an estimate of the position accuracy and the supporting reconnaissance (fix) platforms, (3) the direction and speed of movement during the past six hours (past 12 hours in the Southern Hemisphere) and (4) the intensity and radial extent of over 35, 50 and 100-kt surface winds when applicable. At forecast intervals of 12, 24, 36, 48 and 72 hours (12, 24, 36 and 48 hours in the Southern Hemisphere), information on a tropical cyclone's anticipated position, intensity and wind radii are provided. In addition, vectors indicating the mean direction and mean speed of motion between forecast positions are included in all warnings. Warnings in the western North Pacific and North Indian Ocean are issued every six hours valid at standard synoptic times of 0000Z, 0600Z, 1200Z and 1800Z. Warnings in the Southern Hemisphere are issued every 12 hours at 0000Z and 1200Z or 0600Z and 1800Z unless U.S. assets are threatened then warnings are issued every six hours with forecasts valid out to 72 hours. All warnings are released to the communications network no earlier than synoptic time and no later than synoptic time plus two and one half hours. This ensures recipients of having all warnings in hand by synoptic time plus three hours (0300Z, 0900Z, 1500Z and 2100Z).

(b) Tropical Depression Warning -- Issued only in the western North Pacific for tropical cyclones that are not expected to reach tropical storm intensity. A Tropical Depression warning is issued under the standard MANOP and contains the same information as a Tropical Cyclone Warning but is only issued every 12 hours at standard synoptic times and only extends to the 36-hour forecast period.

Prognostic Reasoning Message -- Issued with the 0000Z and 1200Z TC warnings (0600Z and 1800Z as needed), in the western North Pacific to discuss the forecast rationale for the specific JTWC warning. Prognostic reasoning messages are technical in nature and are prepared for meteorologists to complement each warning. In addition to this message, limited prognostic reasoning information is provided in the remarks section of warnings whenever significant forecast changes are made or when deemed appropriate by the Typhoon Duty Officer (TDO).

Note: JTWC coordinates the transfer of tropical warning responsibility for tropical cyclones entering or exiting its AOR. For tropical cyclones crossing 180° in the North Pacific Ocean, JTWC coordinates with the Central Pacific Hurricane Center (CPHC), Honolulu via Naval Pacific Meteorology and Oceanography Center (NPMOC), Pearl Harbor. For the South Pacific Ocean, JTWC coordinates with NPMOC. In the event JTWC should become incapacitated, the Alternate Joint Typhoon Warning Center (AJTWC), collocated with NPMOC, assumes JTWC's functions. When a tropical cyclone is forecast to become an extratropical cyclone, JTWC coordinates the transfer of warning responsibility with the appropriate Naval Pacific Meteorology and Oceanography Regional Center, which assumes warning responsibilities for the extratropical cyclone.

7.2.1. DATA

To monitor all tropical weather activity in JTWC's AOR, numerous sources of data are used. The following items make up a comprehensive list of data sources available:

1. Conventional -- These data consist of land/ship surface synoptic, buoy, commercial and military aircraft (AIREPS) observations recorded within six hours of synoptic times. These data are hand-plotted and hand analyzed in the tropics for the surface/gradient and 200-mb levels. These analyses are prepared twice daily from 0000Z and 1200Z synoptic data. Also, FNMOC supplies JTWC with computer generated analyses and prognoses (from 0000Z and 1200Z synoptic data) for the surface, 850-mb, 700-mb, 500-mb, 400-mb and 200-mb levels and for the deep layer mean winds. Conventional data are also plotted hourly, or as needed, when tropical cyclones pass near observing stations.

2. Computer -- Numerical and statistical guidance and fields are routinely available from FNMOC. Other sources of selected numerical data and fields are available from other sources including: the National Meteorological Center, Japanese Meteorological Agency, Australian Bureau of Meteorology and UK Meteorology Office.

3. Meteorological Satellite -- Imagery recorded at USAF/USN ground sites and USN ships provides day and night coverage in JTWC's AOR and is the primary source of tropical cyclone surveillance. Interpretation of imagery provides a TDO with tropical disturbance and tropical cyclone position estimates and estimates of current and forecast intensities (Dvorak, 1984). Tactical satellite sites and AFGWC receive and analyze Special Sensor Microwave/Imagery (SSM/I) data to provide estimates of the radial extent of 35-kt winds near tropical cyclones.

4. Radar -- Land-based radar observations (RADOB) are used to position tropical cyclones based on spiral rainband features and/or wall cloud signatures. Once a well-defined tropical cyclone moves within range of radar sites, RADOBs are invaluable for determining tropical cyclone position and motion. Doppler radar's, such as the WSR-88D on Guam, have added a new dimension, radial velocity, to describe the structure of a tropical cyclone. Along the air routes, pilot reports from transiting aircraft, using their airborne radar's, also provide supplemental airborne radar fixes of tropical cyclones.

5. Drifting Buoys -- Using Service ARGOS, drifting buoys transmit data to the TIROS-N polar orbiting satellites, which in turn, re-transmit the data. If the satellite is above the horizon, the re-transmission is received and decoded by a Local User Terminal (LUT) located at JTWC. In addition to re-transmissions, all buoy data is stored aboard these satellites for later download to major processing centers. NOAA/NESDIS disseminates these processed data via the Automated Weather Network (AWN) and Global Telecommunications Service (GTS).

6. Automatic Meteorological Observing Stations (AMOS) -- With the cooperation of the Naval Meteorology and Oceanography Command, NOAA and the Department of the Interior a network of 20 AMOS sites are planned for Micronesia. These sites have a primary transmission capability to geostationary satellite data collection systems (DCS) with a backup to Service ARGOS on the NOAA polar orbiters. As of 1 January 1996, 11 of the 20 AMOS sites were installed. Additionally, NWS maintains two HANDAR sites on the islands of Rota and Tinian, which uplink data to geostationary DCS, and four HANDAR sites on Guam with landline readouts.

7.2.2. OBJECTIVE FORECAST AIDS

JTWC's objective aids are classified into one of four categories. A brief discussion of each aid is listed below:

1. Climatological -- This aid uses past motion of the tropical cyclone and average motions of selected historical tropical cyclones without application of any regression analysis to minimize average forecast error for some dependent data set. Applicable JTWC aids are: extrapolation (XTRP), climatology (CLIM) and typhoon analogs (TYAN). TYAN guidance is stratified into two separate outputs. The first output, straight (STRT), is based on all straight-running tracks. The second output, recurver (RCVR), uses only those tropical cyclones that subsequently recurve. CLIM and TYAN use the same historical data bases, but TYAN applies more restriction to which tropical cyclones are selected for producing the forecast.

2. Statistical -- The common feature of these aids is regression analysis is used to minimize forecast error for a dependent data set. Usually the 24, 48 and 72-hour forecast positions are the results of regression equations that use various types of measured quantities for input. These inputs may be any combination of parameters from the present tropical cyclone, historical storms, (climatology), synoptic analyses and numerical prognoses. Statistical regression models that use only climatology and past motion of the present tropical cyclone are known as CLIPER-class models (climatology and persistence). JTWC's CLIPER-class model is known as CLIP and is run in every basin in the AOR. Guidance that uses only present storm data and data from synoptic analyses is known as statistical-synoptic models, such as the tropical cyclone acceleration prediction technique (TAPT) which correlates track type and movement with features in the upper-level wind field. Models that use present tropical cyclone data and data from numerical prognoses are called statistical-dynamic. JTWC's Colorado State University Model (CSUM) which is used only in the Northern Hemisphere is a statistical-dynamical model. JTWC92 (JT92) is also a statistical-dynamical model used for the western North Pacific. Based on NOGAPS deep-layer mean flow, five internal sub-models are blended and repeated to produce the final JT92 guidance, which yields tropical cyclone 12-hourly positions out to 72 hours.

3. Dynamic -- These aids are based on numerical integration with mathematical equations that approximate the physical behavior of the atmosphere to varying degrees of sophistication. Numerical guidance is derived in two different ways. The most sophisticated approach is to actually track the movement of a tropical cyclone vortex which is either explicitly resolved by or bogussed into a global or regional numerical model. Such guidance is available to JTWC from FNMOC's NOGAPS (NGPS) global model, NGPS vortex tracker (NGPX) and the One-way influence Tropical Cyclone Model (OTCM). NGPS, NPGX and OTCM guidance are available throughout JTWC's AOR. A simpler approach in numerical forecasting is to use either global or numerical model wind fields to compute a steering flow that advects a point vortex. The FNMOC beta and advection model (FBAM) is an operational steering model that uses NGPS deep-layer mean fields to compute steering. In addition, selected guidance is available from the Japanese Meteorological Agency's (JMA) Typhoon Model (JTYM), United Kingdom Meteorological (UKMet) Office at Bracknell (EGRR) and National Meteorological Center (NMC).

4. Hybrid -- These aids combine elements of two or more of the above categories. Half persistence and climatology (HPAC) equally weights the forecasts given by XTRP and CLIP. The blended (BLND) aid uses a simple average of JTWC's primary forecast aids: OTCM, CSUM, FBAM, JT92, CLIP and HPAC. Weighted (WGTD) uses the same input as BLND, but performs a weighted average: OTCM (29%), CSUM (22%), FBAM (14%), JT92 (14%), CLIP (7%) and HPAC (14%). The dynamic average (DAVE) aid

takes a simple average of the following dynamic guidance: NGPS, OTCM, CSUM, OTCM, JT92, FBAM, EGRR and JTYM. The principal advantages and disadvantages of the four categories of aids follow:

(a) Climatological -- With the expectation of error in present tropical cyclone position, the principal advantage of these aids is their generally insensitivity to initialization problems caused by insufficient and/or misrepresentative data. The principal disadvantage is, by definition, they can only give the average behavior of tropical cyclones under the conditions specified. That is, climatology can never handle ac climatological situations well. The analog approach attempts to minimize this problem by restricting the historical data base to a small subset that hopefully represents synoptic conditions that are fairly close to those influencing the present tropical cyclone.

(b) Statistical -- By seeking to minimize the error of some dependent data set, the principal advantage of the statistical aid is it automatically accounts for known and unknown systematic biases caused by data distribution, etc. The principal disadvantage is, like climatology, statistical regression gives forecasts that conform to the average behavior of storms in the dependent data set used in the regression analysis. Again, ac climatological situations are generally not handled well. The statistical-synoptic and statistical-dynamic aids are also subject to the negative influences of erroneous or missing data that affect the dynamic models.

(c) Dynamic -- The principal advantage is that they are sensitive to the current and future synoptic structure of the atmosphere, as represented by the model, and thus can better handle ac climatological situations. The principal disadvantage of numerical models is their sensitivity to insufficient or erroneous data (typically inducing a “misplaced vortex”) which results in forecasts that, even in the short term, are initialized with the wrong direction/speed. Interestingly, the more sophisticated the numerical model is, the more sensitive it is to inaccurate initialization due to data limitations. Also, the more sophisticated the model, the more degrees of freedom it has, and the more rapidly its forecasts can depart from reality due to nonlinear growth of data-induced initialization error. As a result of this weakness, numerical models often have a persistence feature added, to ensure the model vortex at least starts out in the right direction.

(d) Hybrid -- These aids attempt to capitalize on the strengths of the other types of aids by applying statistical weighting factors based on their past performance.

7.2.3 ANALYSIS

Detection -- The first indication of the formation of a tropical cyclone will vary with the type of system and data available. Satellite data usually provides the first indication of significant tropical cyclone development, even in data rich areas, and are often the only source of detection over many ocean areas.

1. Positioning

(a) Satellite imagery provides the primary source of tropical cyclone fixes. Land radar, synoptic and airborne radar on transiting aircraft are secondary sources. Each satellite derived tropical cyclone position is assigned a Position Code Number (PCN) which is a measure of the positioning confidence. The PCN is determined by a combination of the availability of visible landmarks in the image that can be used as references for precise gridding of the image and the degree of organization of the tropical cyclones cloud system. In the absence of any noted landmass features, the satellite nodal point is used for gridding which is not nearly as accurate as land mass gridding.

(b) Radar positions of tropical cyclone centers are very reliable when a cyclone is within a radar stations range of coverage and the rainbands are well organized. However, the accuracy of radar fixes for well defined cyclones, or for cyclones with poorly defined rainbands, should be expected to decrease as the radar range increases.

(c) Synoptic reports are of great value if the tropical cyclone passes over, or very near, a land station, buoy or ship. Center fixes constructed using synoptic data that is displaced from the center of tropical cyclone are usually not very accurate. Transiting aircraft can provide airborne radar fixes when the tropical cyclone is near their flight path.

(d) Extrapolation becomes the basis for the warning only if no fixes are available for 6 hours before the starting valid time for the warning.

Note: With regard to positioning, in general, it is important to avoid reacting too quickly to apparent radical changes in cyclone direction or speed indicated by the last fix. All positioning methods are accurate only to within certain limits and short term oscillations of a cyclone center about the main track are common. These oscillations may result from the actual "wobble" (trochoidal motion) of the center of the tropical cyclone, or be due to errors in the raw fix data or, a combination of both.

2. Intensity -- For tropical cyclones in JTWC's AOR, satellite intensity measurements are frequently the only data available. These estimates are based on the Dvorak (1984) technique. The Dvorak intensity estimation technique provides a good estimate of the current intensity of a tropical cyclone, and involves procedures and rules which combine meteorological analysis of satellite imagery with a model of expected tropical cyclone development. The current intensity follows from the final T-number. The current intensity relates to a maximum sustained 1-minute mean surface wind and a minimum sea-level pressure (Table 7.1)

<u>T-number</u>	<u>Estimated Wind Speed (kt)</u>	<u>MSLP (mb)</u>
0.0	< 25	----
0.5	25	----
1.0	25	----
1.5	25	----
2.0	30	1000
2.5	35	997
3.0	45	991
3.5	55	984
4.0	65	976
4.5	77	966
5.0	90	954
5.5	102	941
6.0	115	927
6.5	127	914
7.0	140	898
7.5	155	879
8.0	170	858

Table 7.1 Estimated Maximum Sustained 1-minute Mean Wind Speed (kt) as a Function of Dvorak T-number and Minimum Sea-Level Pressure (MSLP)

3. Wind Radii -- The analysis of a tropical cyclones wind radii is accomplished using a combination of conventional and satellite data. The usefulness of conventional land buoy and ship surface observations are generally limited to helping define the 35-kt radius, due to the sparcity of the observation sites and low probability of any given tropical cyclone passing very near a reporting point. Special Sensor Microwave Imagery (SSM/I) data may also be available to assist in further defining the 35-kt radius, depending on tropical cyclones location and polar orbiter satellite coverage. Additionally, scatterometer data from the European Space Agency's (ESA) Remote Sensing Satellite (ERS) provides surface wind vectors over the ocean areas. The upper limit for both the SSM/I and ERS wind speed is 50 kt. Conventional surface observations may occasionally assist in defining the 50-kt or greater wind radii. For tropical cyclones for which the Dvorak intensity analysis exceeds 100 knots, the 100-kt wind radius is inferred from the satellite-based estimation of eye size.

7.2.4. FORECASTING

Track -- In preparing the JTWC official forecast, the TDO evaluates a wide variety of information and employs a number of objective and subjective techniques. Because tropical cyclone track forecasting has and continues to require a significant amount of subjective input from the TDO, detailed aspects of the forecast-development process will vary somewhat from TDO to TDO, particularly with respect to the weight given to any

of the available guidance. JTWC uses a standardized, three-phase tropical cyclone motion forecasting process to improve not only track forecast accuracy, but also intensity forecast accuracy and forecast-to-forecast consistency.

1. Field Analysis Phase -- NOGAPS analyses and prognoses at various levels are evaluated for position, development, and movement of not only the tropical cyclone, but also relevant synoptic features such as: 1) subtropical ridge circulations, 2) mid-latitude short/long-wave troughs and associated weaknesses in the subtropical ridge, 3) monsoon surges, 4) cyclonic cells in the Tropical Upper-Tropospheric Trough (TUTT), 5) other tropical cyclones and 6) the distribution of sea surface temperature. This process permits the TDO to develop an initial impression of the environmental steering influences to which the tropical cyclone is and will be subjected to as depicted by NOGAPS. The NOGAPS analyses are then compared to the hand-plotted and analyzed charts prepared by the TDO and to the latest satellite imagery in order to determine how well the NOGAPS-initialization process has conformed to the available synoptic data and how well the resultant analysis fields agree with the synoptic situation inferred from the imagery. Finally, the TDO compares both the computer and hand-analyzed charts to monthly climatology in order to make a preliminary determination of to what degree the tropical cyclone is, and will continue to be, subjected to a climatological or non-climatological synoptic environment. Noting latitudinal and longitudinal displacements of the subtropical ridge and long-wave midlatitude features is of particular importance and will partially determine the relative weights given to climatologically- or dynamically-based objective forecast guidance.

2. Objective Techniques Analysis Phase -- By applying the guidance of the "Systematic and Integrated Approach" (Carr and Elsberry, 1994), the TDO can relate the latest set of guidance given by JTWC's suite of objective techniques with the NOGAPS model prognoses and currently observed meteorological conditions. This allows the TDO to evaluate the objective techniques guidance to the following principles. First, the degree to which the current situation is considered to be, and will continue to be, climatological is further refined by comparing the forecasts of the climatology-based objective techniques, dynamically-based techniques, and past motion of the present storm. This assessment partially determines the relative weighting given the different classes of objective techniques. Second, the spread of the set of objective forecasts, when plotted, is used to provide a measure of the predictability of subsequent motion, and the advisability of including a moderate probability alternate forecast scenario in the prognostic reasoning message or warning (outside the western North Pacific). The directional spread of the plotted objective techniques is typically small well-before or well-after recurvature (providing high forecast confidence), and is typically large near the decision-point of recurvature or non-recurvature, or during a quasi-stationary or erratic movement phase. A large spread increases the likelihood of alternate forecast scenarios.

3. Construct Forecast Phase -- The TDO then constructs the JTWC official forecast giving due consideration to the: 1) extent to which the synoptic situation is, and is expected to remain, climatological; 2) past statistical performance of the various objective techniques on the current storm; and 3) known properties of individual objective techniques given the present synoptic situation or geographic location. The following guidance for weighting the objective techniques is applied:

- (a) Weight persistence strongly in the first 12 to 24 hours of the forecast period.
- (b) Give significant weight to the last JTWC forecast at all forecast times, unless there is significant evidence to warrant a departure. (Also consider the latest forecasts from regional warning centers, if applicable.)
- (c) Give more weight to the techniques that have been performing well on the current tropical cyclone and/or are expected to perform well in the current and anticipated synoptic situations.
- (d) Stay within the "envelope" determined by the spread of objective techniques forecasts unless there is a strong specific reason for not doing so (e.g., all objective forecasts start out at a significant angle relative to past motion of the current tropical cyclone).
- (e) Apply the "Systematic and Integrated Approach" (Carr and Elsberry, 1994), using conceptual models of recurring, dynamically-related meteorological patterns with the traits of the numerical and objective aid guidance associated with the specific synoptic situation.

Intensity -- The empirically derived Dvorak (1984) technique is used as a first guess for the intensity forecast. The TDO then adjusts the forecast after evaluating climatology and the synoptic situation. An

interactive conditional climatology scheme allows the TDO to define a situation similar to the system being forecast in terms of location, time of year, current intensity and intensity trend. Synoptic influences such as the location of major troughs and ridges, and the position and intensity of the TUTT all play a large part in intensifying or weakening a tropical cyclone. JTWC incorporates a checklist into the intensity forecast procedure. Such criteria as upper-level outflow patterns, neutral points, sea-surface temperatures, enhanced monsoonal or cross-equatorial flow and vertical wind shear are evaluated for their tendency to enhance or inhibit normal development, and are incorporated into the intensity forecast process through locally developed thumb rules. In addition to climatology and synoptic influences, the first guess is modified for interactions with land, other tropical cyclones and extratropical features. Climatological and statistical methods are also used to assess the potential for rapid intensification (Mundell, 1990).

Wind Radii -- Since the loss of dedicated aircraft reconnaissance in 1987, JTWC has turned to other data sources for determining the radii of winds around tropical cyclones. The determination of wind radii forecasts is a three-step process:

1. First, low-level satellite drift winds, SSM/I 35-kt wind speed analysis and synoptic data are used to derive the current wind distribution.

2. Next the first guess of the radii is determined from statistically-derived empirical wind radii models. JTWC currently used three models: the Tsui model, the Huntley model, and the Martin-Holland model. The latter model uses satellite-derived parameters to determine the size and shape of the wind profile associated with a particular tropical cyclone. The Martin-Holland model also incorporates latitude and speed of motion to produce an asymmetrical wind distribution. These models provide wind distribution analyses and forecasts that are primarily influenced by the intensity forecasts. The analyses are then adjusted based on the actual analysis from step 1. and the forecasts are adjusted appropriately.

3. Finally, synoptic considerations, such as the interaction of the cyclone with mid-latitude high pressure cells, are used to fine-tune the forecast wind radii.